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Advancing socio-technical systems thinking: A call for bravery

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Abstract

Socio-technical systems thinking has predominantly been applied to the domains of new technology and work design over the past 60 years. Whilst it has made an impact, we argue that we need to be braver, encouraging the approach to evolve and extend its reach. In particular, we need to: extend our conceptualization of what constitutes a system; apply our thinking to a much wider range of complex problems and global challenges; and engage in more predictive work. To illustrate our agenda in novel domains, we provide examples of socio-technical perspectives on the management of crowd events and environmental sustainability. We also outline a research and development agenda to take the area forward.

Highlights

- A wider conceptualization of what constitutes a system, e.g., crowd events.
- A wider range of applications, to include global challenges, e.g., sustainability.
- Framework for more predictive analysis, e.g., to identify and mitigate risks.
- Retrospective case studies to generate lessons for use predictively.
- Research and development agenda to advance socio-technical practice.

Keywords

Systems; Crowds; Sustainability; Prediction

1. Introduction

Socio-technical systems theory has enjoyed around 60 years of development and application internationally by both researchers and practitioners (e.g., Baxter & Sommerville, 2011; Carayon, 2006; Cherns, 1976, 1987; Clegg, 2000; Eason, 1988, 2007; Mumford, 1983, 2006; Pasmore & King, 1978; Trist & Bamforth, 1951; van Eijnatten, 1997; Waterson, 2005). The over-arching philosophy, embracing the joint design and optimization of organizational systems (incorporating both social and technical elements), has maintained its practical relevance and has seen increasing recognition and acceptance by audiences outside the social sciences (Eason, 2008). Such successes can be attributed, in part, to the continuing evolution of socio-technical systems thinking and practice.

In this paper, we argue that people engaged in socio-technical thinking need to extend their conceptualizations of 'systems', apply the core ideas to new domains reaching beyond the traditional focus on new technologies, and, at the same time, become involved in predictive work. The underlying call is to be braver in all three respects.

To these ends, we first reflect upon the progress of socio-technical systems thinking to-date and the impact it has achieved. We then make the case for extending socio-technical systems theory to new domains. To do this, we describe a framework for socio-technical analyzis and design which we use to provide two illustrative examples of its application in novel settings. In each of the examples we identify the potential and importance of undertaking predictive work. We then outline a research and development agenda that will help take the domain forward. We argue that the application of socio-technical thinking to new areas may help address significant contemporary challenges, thereby extending our social impact and reach, and, at the same time, offering opportunities for theoretical development.

We should be clear from the outset; whilst we draw on examples of our own work to illustrate the case for extending socio-technical thinking to new domains, this paper does not focus on the description of our method (or indeed on its comparison with other methods) and is not a 'methods' paper per se. Rather, we seek to illustrate the need for the socio-technical community to move beyond its traditional focus on new technologies to a broader concern for complex systems, whatever form these may take. Although this will still involve technologies, tools and infrastructures to some extent, there is a need for a shift in our mindsets to meet this challenge. We now turn to the emergence of socio-technical systems thinking and where it has had its greatest impact thus far.

2. Emergence of socio-technical systems thinking

Socio-technical systems thinking grew out of work conducted at the UK Tavistock Institute into the introduction of coal mining machinery. This identified the interrelated nature of technological and social aspects of the workplace (Trist & Bamforth, 1951; Trist, Higgin, Murray, & Pollock, 1963). The introduction of new machinery into coal mines without analysis of the attendant changes in working practices highlighted the need for consideration of behavioral issues during the design and implementation of new technologies. These, and other similar studies, led to the emergence of socio-technical systems theory (van Eijnatten, 1997).

This early work is reflected in the core philosophy of socio-technical systems theory, namely that *"design is systemic"* (Clegg, 2000, p. 465). The theory advocates consideration of both technical and social factors when seeking to promote change within an organization, whether it concerns the introduction of new technology or a business change program (Cherns, 1976). Organizations can be considered complex systems, comprising many interdependent factors. Designing a change to one part of the system without considering how this might affect, or require change in, the other aspects of the system will limit effectiveness (Hendrick, 1997).

Although the underlying philosophy has remained largely unchanged, the specific principles and applications have evolved to reflect the changing nature of work, technology and design practices. The emphasis has shifted from an early focus on heavy industry (e.g., Rice, 1958; Trist & Bamforth, 1951), to a gradual broadening of enquiry to advanced manufacturing technologies (e.g., Dankbaar, 1997), through to office-based work and services (e.g., Clegg, 2000; Mumford, 1983; White, Wastell, Broadhurst & Hall, 2010). The common theme across these contexts has been a focus upon the introduction of new technologies.

Socio-technical systems theory has achieved some success in helping inform the design of new technologies and technology-led change (e.g., Baxter & Sommerville, 2011). The principles have helped guide designers on the potential roles of users and on developing an understanding of how new technology may be used and integrated with existing (and planned) social systems (Mumford, 1983; Klein, 2005). The broad understanding gained through the continued study of technological design has enabled a reinterpretation of socio-technical principles to reflect the challenges of contemporary information and communications technologies (Clegg, 2000). The fruits can be seen in the way that socio-technical researchers have been able to offer critical reflection and constructive advice on the design of large scale IT projects, such as the National Health Service (NHS) National Programme for Information Technology (NPfIT) (Clegg & Shepherd, 2007; Eason, 2007) and the new IT system supporting the delivery of social care (White, Wastell, Broadhurst & Hall, 2010).

Interestingly, socio-technical tools and approaches are spreading beyond the social sciences, being taken up by colleagues in the IT community (Eason, 2008). This latter point is significant, offering the potential for wider impact, if indeed this does become embedded in the accepted design orthodoxy of IT professionals. The emergence of explicit socio-technical thinking within the initial design stages of IT would also help counter one of the prevailing criticisms of socio-technical design, namely that much of our work has centered on mitigating the impact of IT by redesigning the social aspects of the system or by trying to gain user support, rather than influencing the design of IT itself (c.f., Pasmore, 1994).

In addition to influencing the design of new technologies, socio-technical systems theory has had a significant impact on the social aspects of organizational design, most notably on the design of jobs and ways of organizing work. Its contribution is probably best illustrated by the widespread acceptance of socio-technical concepts such as autonomous workgroups, multi-skilling and user control (Grant, Fried, & Juillerat, 2011; Wall, Kemp, Jackson, & Clegg, 1986). The redesign of jobs and work processes in line with socio-technical theory has helped to deliver both improved work experience for employees and more effective systems. For example, allowing employees the opportunity to resolve problems at source has been linked to a range of outcomes including increased productivity, motivation and well-being (Birdi et al, 2008; Grant et al., 2011).

Whilst these have been the pre-dominant areas of application and impact, socio-technical systems principles and methods have also enjoyed success in other areas, such as accident analysis and causation (e.g., Salmon, Stanton, Lenné, Jenkins, Rafferty, & Walker, 2011). A number of methods for applying a socio-technical mindset to such circumstances have been developed, for instance, the Human Factors Analysis and Classification System (HFACS, Wiegmann & Shappell, 2003), Systems Theoretic Accident Modelling and Process model (STAMP, Leveson, 2004), and Accimap (Rasmussen, 1997). We return to these methods later.

In summary, socio-technical principles and philosophy have been applied successfully in a number of key domains, most notably concerning the design of new technologies and the redesign of work roles. This work has yielded both practical impact (e.g., in the form of new work roles and working practices and, on occasion, modifications to technological design) and theoretical refinement (e.g., the extension of socio-technical design principles).

3. The case for broadening the application of socio-technical systems thinking

We now discuss the potential benefits of extending the approach to new areas. In particular, we highlight how applying socio-technical theory to new work contexts and problems may help drive increased interest and support theoretical development.

Socio-technical systems theory incorporates the idea of design incompletion; the continuing need to review and revise our designs (Cherns, 1976, 1987). Just as the design of organizational systems is on-going, so too should our understanding of socio-technical design be dynamic and open to challenge. We need to explore opportunities to apply socio-technical thinking to new problems, testing the adequacy of existing principles and identifying where we can contribute to new fields of enquiry.

In short, we believe the focus of socio-technical systems research to-date has been too narrow and that there are new contexts and problems that could benefit substantially from socio-technical systems thinking. The relative narrowness of application domains is reflected in reviews of socio-technical systems studies, which reveal the vast majority of research has been conducted in, and continues to concern, the development and implementation of IT systems (for examples see Coakes & Coakes, 2009; editions of the International Journal of Sociotechnology and Knowledge Development, 2010, 2011, 2012). Of course, there are potential benefits to this approach. Conducting research in similar areas allows researchers to build upon previous studies and provides the opportunity to test the reliability of assumptions (c.f., Hodgkinson & Healey, 2008). It also enables researchers to create detailed advice for practitioners. Specifically in the case of IT design, sustained attention may have contributed to raising awareness of the socio-technical approach with other professionals (e.g., Eason, 2007, 2008).

However, there are drawbacks to being too focused upon particular problem domains. One such outcome may be homogeneity of thought, with prevailing ideas less likely to be challenged (c.f., groupthink; Janis, 1972). Socio-technical thinking advocates and promotes the active role of the researcher (Mumford, 2006), with practical experience feeding theoretical development (Cassell & Johnson, 2006). Applying socio-technical thinking to novel situations enables researchers to test how well their ideas hold across domains and provides a potential spur for innovation.

We propose that socio-technical thinking can be applied to a wide range of domains with the potential to increase our practical reach. This is unlikely to occur, however, until there are exemplar studies demonstrating the value of investing in socio-technical ways of thinking in such new areas. In the next section we illustrate the argument using examples from our own research.

4. New application domains

In this section we describe two areas in which we have deployed socio-technical systems thinking. The intent is to illustrate the breadth of opportunities that exist and to demonstrate how this thinking can be undertaken in a predictive way (rather than after the event). First, however, we provide an outline of the framework that we have used in these and other studies.

4.1. A socio-technical framework

Our framework is based on an initial schema by Leavitt (1965) and subsequently used by others (including, for example, Handy, 1993; Scott Morton, 1991). Leavitt's (1965) framework was developed through his experience of undertaking organizational change and focused on the relationships between people, tasks, structures and technologies. He argued for the interrelatedness of these system components and for the need for their joint consideration. We have extended this framework, through a mixture of action research and retrospective case study analysis, to represent organizational systems using six interrelated elements (see Challenger & Clegg, 2011), embedded within an external environment. The core idea is that any complex organizational system can be represented in the form of a hexagon, as summarized in Figure 1.

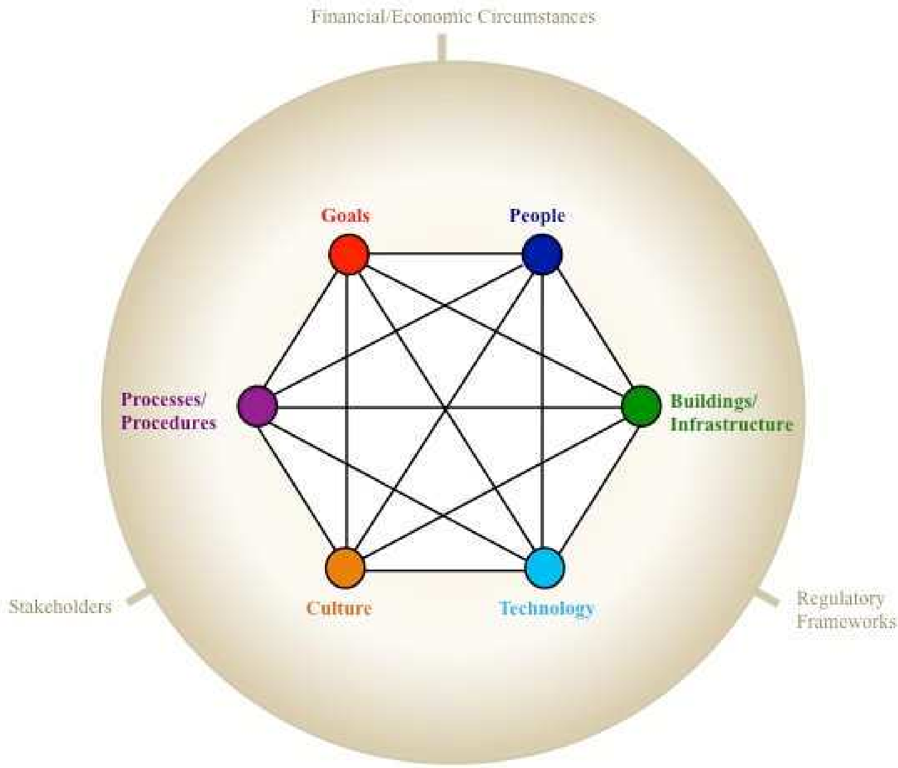


Figure 1: Socio-technical system, illustrating the interrelated nature of an organizational system, embedded within an external environment.

Thus, for example, a work system will usually have a set of goals and metrics, involve people (with varying attitudes and skills), using a range of technologies and tools, working within a physical infrastructure, operating with a set of cultural assumptions, and using sets of processes and working practices. The system sits within a wider context, incorporating a regulatory framework, sets of stakeholders (including customers), and an economic/ financial environment. The importance of these external factors will vary with each system, as will the ways in which their influence is exerted. For example, a particular regulatory framework may well influence the goals pursued by an organization and the metrics in use.

This schema is an attempt to provide a simple yet powerful representation of the interdependent nature of work systems, providing a framework for analyzing the linkages and relationships between the different social and technical aspects. The potential value of applying such an approach is that it provides a structured and systematic way of analyzing a variety of complex systems, problems and events. It is worth noting that, unlike some other prominent socio-technical methods (e.g., HFACS, Accimap and STAMP), our approach is not limited to, or primarily focused upon, accident analysis; rather, it offers a flexible alternative that may be applied to a range of domains and problems (as will be demonstrated in the featured case studies). Similarly to Soft Systems Analysis, and to a degree STAMP, it also lends itself to both predictive work and that focused on design (c.f., Leveson, 2012).

It is beyond the scope of this paper to describe in detail how the framework is deployed in any particular project and, indeed, as mentioned previously, that is not our focus here. We do, however, provide an overview of the major steps involved in applying the framework to analyzing and understanding existing systems (see Table 1).

Suffice it to say here that the framework is populated in the same way as other conceptual frameworks using a process involving: data gathering, analysis and interpretation using the framework; summarizing the findings; testing the results with stakeholders; and iterating and amending as necessary (See, Challenger, Clegg, & Robinson, 2010a; 2010b; and Challenger & Clegg, 2011, for more fully worked examples). We now illustrate the use of this framework in two examples.

4.2. Crowd events

Socio-technical thinking can be used as a framework to analyze crowd behaviors under both normal and emergency conditions, and to help guide and facilitate crowd event preparation and management. The aim is to ensure not only that both social and technical factors are considered during decision-making but, also, that differing organizational perspectives are acknowledged, suitable compromises reached and subsequent actions coordinated. Crowd event preparation and management, for example, involves input from multiple agencies, such as the venue operators, emergency services, local authorities, event planners and stewards.

The importance of effective, coordinated crowd event preparation and management is highlighted by the occurrence of disasters, such as the Hillsborough football stadium disaster (Taylor, 1989, 1990), the King's Cross Underground Fire (Fennell, 1988) and the Bradford City Fire (Popplewell, 1985).

Focusing on the Hillsborough football stadium disaster (1989), the application of socio-technical systems thinking highlights how the prevailing mindsets and values of the time (held by the police, the other authorities involved, the media and the wider public) were focused almost exclusively on hooliganism (culture). This prompted a concern for security ahead of safety (goals) and influenced actions taken both before

Table 1. The steps involved in analyzing and understanding an existing socio-technical system

Step	***Task description***
1	Gather relevant data from appropriate sources, including key actors, stakeholders, subject matter experts, and internal and external documents.
2	Analyze and classify data, using techniques such as template analysis (King, 2004). Initial template consists of the socio-technical framework.
3	Identify and group key system factors. Visually represent the groups of factors on each node of the framework.
4	Consider the implication of the external environment in which the system is embedded within the node to which it relates.
5	Systematically consider relationships between each set of factors, and identify contingencies and direction of relationships.
6	Visually inspect the hexagon framework and assess underexplored or related areas, and reappraise evidence or seek input from colleagues and subject matter experts (e.g., with expertise in buildings and infrastructure).
7	Add any additional relevant factors that emerge from the data during analysis or following previous step.
8	If appropriate: Generate a timeline of key factors leading up to the event or scenario, grouped by the six factors. Classify as: long-standing issues (3+ months); issues immediately preceding the event (0 – 3 months); and factors involved on the day.
9	Test analysis on key stakeholders for accuracy, omissions and interpretations, and modify as necessary after discussion.
10	Generate key inferences regarding the system and how it works.

and during the event. This then interacted with poor inter-agency communication and coordination before and during the match (processes and procedures), along with a lack of end-user involvement and expert input to preparations (people), meaning those closely involved were unsure of how to respond appropriately. The situation was further worsened by failing radios (technology) and an outdated, inappropriately laid out and ill-equipped ground (buildings and infrastructure) (Challenger & Clegg, 2011). A simplified representation of the key contributory factors is presented in Figure 2, and shown as a timeline in Table 2 (See Challenger & Clegg, 2011, for a more detailed discussion of the underpinning causes).

The analysis of the Hillsborough disaster provides an opportunity to draw brief comparisons between the results gained using our method of analysis and those produced by an alternative method, Accimap (see, Salmon et al, 2011). Both reach fundamentally similar conclusions regarding key contributory factors; however, a few differences emerge. Although both sets of diagrams identify similar factors, the levels at which they are represented differ. For example, the Accimap approach captures greater detail regarding individual factors, such as physical processes and actor activities, whilst our own analysis aggregates to higher levels. Furthermore, our method focuses upon identifying cross-system relationships between different system components (e.g., culture and goals) to encourage the development of system level advice and improvement, rather than mapping cross-level relationships within individual system components (e.g., between "inadequate operations orders" and "failure to open perimeter gates") as with Accimap (c.f., Waterson, 2009). It is also apparent that our analysis includes a greater focus upon goals, mindsets and the wider culture than is captured in the Accimap diagram. Accimap explicitly captures the regulatory and external agency influences on the event (e.g., regarding safety certificates) whereas these are viewed as indirect influences in our analysis. Also notable is that our output provides an overarching timeline of major factors contributing to the disaster and their temporal ordering. The Accimap approach, by comparison, provides a map of the relationships and permits tracing of a causal chain, though the timings involved are less explicit. Thus, both analyzes provide valuable insights into the system failures that contributed to the disaster and permit guidance to be drawn.

In our view, a systems perspective is useful in helping analyze and understand what happened. But more than that, such an approach can also be used predictively by event planners, managers and the various agencies, as a framework to help identify and mitigate risks that typically underpin crowd-related disasters and, thereby, enhance event preparation and management.

An example of this can be seen in Challenger et al's (2010a) application of this framework predictively to identify key risks and contingencies concerning crowd management prior to the London 2012 Olympic Games.

Challenger and Clegg (2011) analyzed the circumstances involved in three well researched and documented cases, namely the Hillsborough football stadium disaster (Taylor, 1989, 1990), the King's Cross underground fire (Fennell, 1988) and the Bradford City fire (Popplewell, 1985). In each case they utilized a mix of archival materials (including independent reports, enquiry documents and interviews), academic papers and interviews with a range of subject matter experts. They also subsequently tested their analysis with experts in the area to help validate their conclusions.

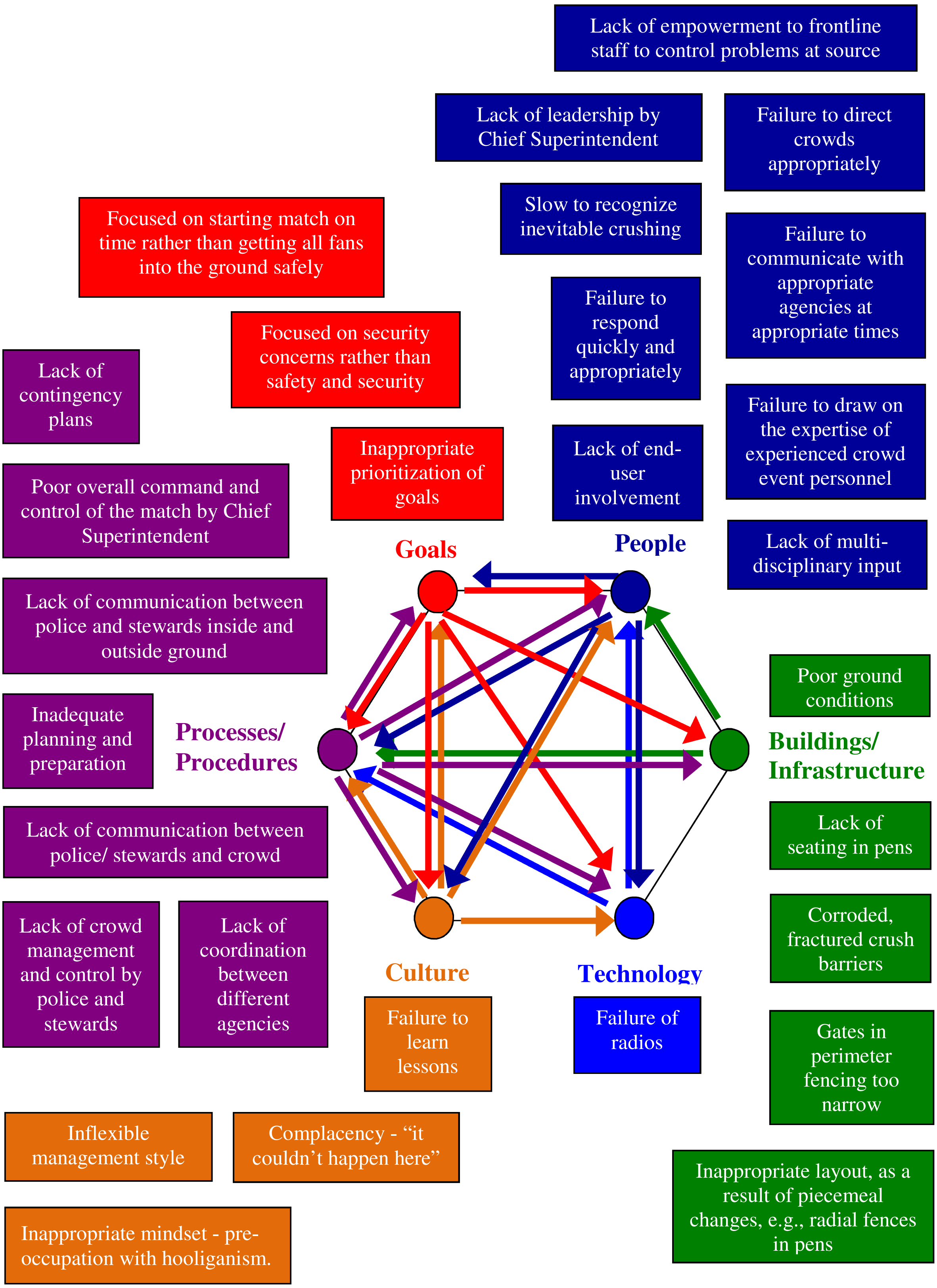


Figure 2: The Hillsborough Football Stadium Disaster from a systems perspective (adapted from Challenger & Clegg, 2011, p.348).

Table 2. Timeline of the interrelated factors underpinning the Hillsborough football stadium disaster (1989)

	Culture	*Goals*	*Buildings/ Infrastructure*	*Technology*	*Processes/ Procedures*	*People*
Long-standing issues	• Complacency • Inappropriate mindset – hooliganism focus • Failure to learn lessons • Inflexible management style	• Focused on security	• Poor ground conditions • Corroded crush barriers • Inappropriate layout • Gates in perimeter fence too narrow • Lack of seating		• Lack of systems thinking	
Weeks prior to match		• Little concern for safety			• Poor planning and preparation • Lack of contingency plans	• Little end-user involvement • Little multi-disciplinary input • Lack of expert input
On the day		• Poor prioritization of goals • Focused on starting match on time		• Failure of radios	• Poor command and control • Lack of inter-agency communication and coordination • Lack of communication with crowds • Lack of crowd management and control	• Lack of overall control, leadership and responsibility • Slow response • Failure to direct crowds appropriately • Poor communication • Lack of frontline empowerment

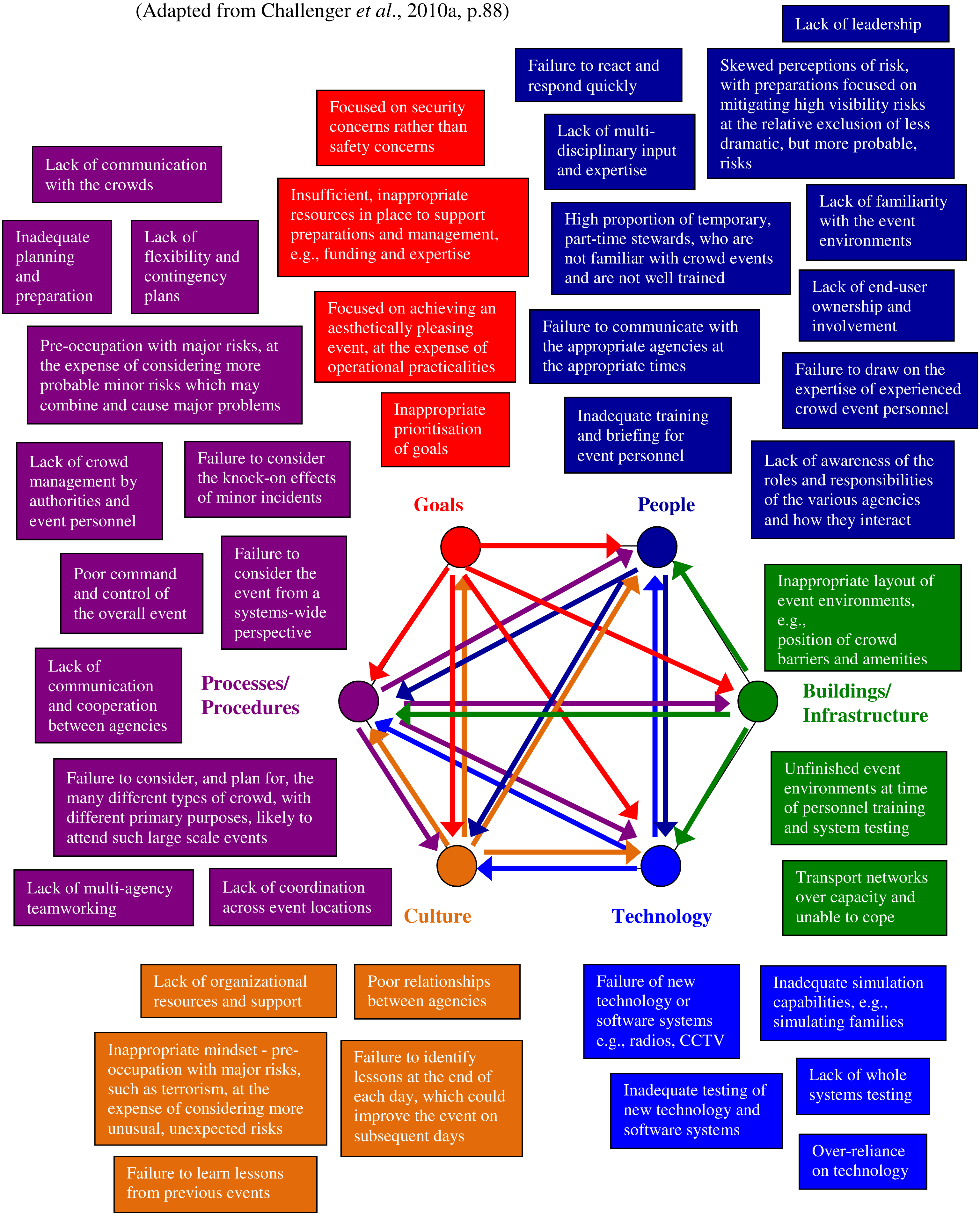
In each of these three disasters, analysis showed that problems resulted from complex system failures, where multiple interdependent factors combined in such a way as to cause problems (Challenger & Clegg, 2011). This is similar in emphasis to the perspectives offered by Reason (1995) and Perrow (1984). The common factors included myopic mindsets, complacent attitudes, failure to learn lessons or heed expert advice, poor training and education, poor communication, lack of leadership, failures of technology, inappropriately designed infrastructures, lack of role clarity and poor inter-agency coordination (Challenger & Clegg, 2011).

Identifying common factors contributing to systems failures and disasters in retrospective cases can aid the specification of potential risk factors for future crowd events. For example, given that poor inter-agency coordination was found to be an underpinning factor at each of the Hillsborough, King's Cross and Bradford City disasters, it was considered to be a key risk factor for London 2012. Challenger et al (2010a) then supplemented this initial data by interviewing subject matter experts in event preparation (including senior police officers, event organizers and safety experts) and reviewing public documents and policies relating to the event. The resulting diagram (Figure 3) identified the potential risk factors within the system that could impact on crowd management and safety.

Thus, with careful analysis we believe it is possible to examine previous disasters and accidents to make predictions about the circumstances under which they are more likely to occur in the future (see the argument developed by Challenger and Clegg, 2011). We believe this is potentially more helpful than simply saying that such accidents and disasters occur when unique sets of factors combine together in unanticipated ways, but without specifying what these factors may be.

Our argument is that it is possible to use socio-technical frameworks to engage in predictive work and thereby to make substantial contributions to the design and management of major projects. For example, we did not need the National Programme for IT (NPfIT) in the NHS to go wrong before we could offer views, understanding and advice. The same argument holds, at least in principle, to other systems in other domains. Specifically, in the case of NPfIT, a number of academics within the socio-technical tradition offered reasoned and skeptical views of the likely success of the new infrastructure program based on analyzes of earlier work. Predictions were made about the problems that would arise, in particular from the lack of end-user clinical engagement, the lack of attention to the need for organizational, process and role re-design, and the over-emphasis on technology-led change (e.g., Clegg & Shepherd, 2007; Eason, 2007). All of these problems have subsequently been confirmed by various independent analyzes (Cabinet Office Major Projects Authority, 2011; House of Commons Committee of Public Accounts, 2007).

Figure 3: The potential risks associated with the London 2012 Olympics
(Adapted from Challenger *et al.*, 2010a, p.88)



4.3. Environmental sustainability in the workplace

In this second example, we argue that socio-technical thinking can also be applied to help organizations improve their environmental sustainability. Organizational environmental sustainability is affected by a complex interplay of behavioral, technological, organizational, regulatory and financial factors (e.g., Davis & Challenger, in press; Schrader & Thøgersen, 2011). In practice, the majority of organizational initiatives aimed at increasing environmental sustainability are based on system standards (e.g. ISO14001/EMAS) or technological/ building changes (e.g. Energy Performance of Building Directive, EPBD). They often fail to consider human behavior (e.g., Bansal & Gao, 2006). Yet this domain can be seen as a quintessentially socio-technical challenge. The imbalance of research and practice, currently skewed heavily towards the technical and infrastructural elements of the system, highlights the particular need for a socio-technical way of thinking (Davis, Leach, & Clegg, 2011). This is evident from failures of some technical 'solutions'. For instance, researchers and practitioners have noted that although more efficient technologies and innovative building techniques have the potential to increase the environmental performance of workplaces (e.g., Natsu, 2008), they are unlikely to produce the desired environmental gains without adequate consideration of behavioral and organizational factors (Davis & Challenger, 2009).

In particular, an appreciation of the interdependent nature of an organization as a system can help avoid misspecification of technologically driven interventions. A failure to correctly predict, or at least appreciate, how people are likely to behave or respond to sustainable buildings or technologies can lead to their inappropriate design and, subsequently, to unintended consequences and inefficient operation in practice (Wener & Carmalt, 2006).

There are other factors that suggest socio-technical systems theory could have a real impact in driving environmentally sustainable outcomes in the workplace. For example, the themes of end-user engagement and team-based approaches (both central to socio-technical thinking) have been found to play a key role in sustainability initiatives (e.g., Rothenberg, 2003; Siero, Bakker, Dekker, & Van Den Burg, 1996).

One benefit is that socio-technical thinking can help map existing organizational efforts to improve environmental sustainability (Davis et al., 2011). For example, in Figure 4 we identify the approaches and techniques implemented to aid environmental sustainability at the UK plant of a major manufacturing company. Data were gathered using organizational documentation, publicity materials, interviews with management and focus groups with staff. The diagram captures the various initiatives undertaken by the organization, highlights the aspects of the system that they have concentrated on, and makes clear where interdependencies and gaps occur. This analysis helps clarify that goals and culture have so far received relatively little attention, despite such factors being known to be important in supporting workplace environmental sustainability (e.g., Unsworth, Dmitrieva, & Adriasola, 2012). The results of this analysis have been used to inform advice for the organization regarding future initiatives, for example focusing on individual employee goals.

We believe frameworks such as this have a series of potential interrelated uses in this domain. Thus, where existing initiatives are in place, it can be used to identify potential conflicts (for example, where existing processes do not permit employees to apply practices learned on training courses) and to identify potential gaps in coverage (for example, have we paid sufficient attention to employee goals and metrics?). This allows the identification and design of new initiatives. Where such changes are planned, the framework encourages a systemic approach to design, ensuring consideration of both technical and social issues. For instance, the introduction of new feedback devices may require concurrent design of goals, rewards and training. As with the previous example, the framework has the potential to help with both understanding and managing existing systems and designing and managing new ones.

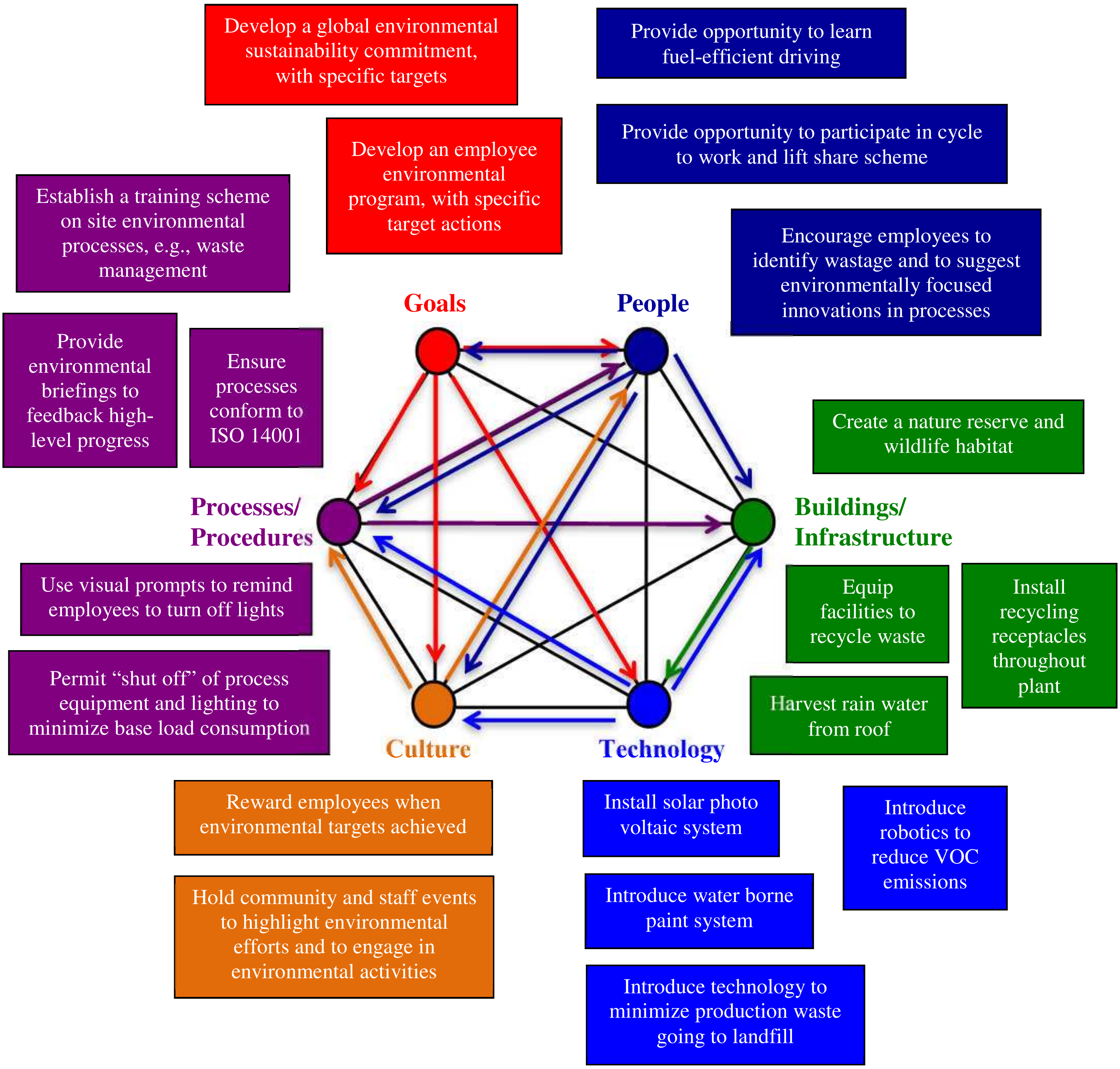


Figure 4: Approaches and initiatives implemented to support greater environmental sustainability at a major UK manufacturing plant.

This example demonstrates the potential for socio-technical systems thinking to be applied more broadly and to help address important challenges facing society (in this case environmental sustainability). Taking on such challenges requires a reappraisal of what we, as a community, hold to be complex systems. In so doing we have highlighted the need for the role of technology within existing environmental initiatives to be balanced with consideration of the wider human and organizational aspects of the system (Davis et al, 2011).

Together these case examples illustrate how socio-technical thinking can be used to make contributions beyond its traditional focus on new technologies and work organization. As stated at the outset, this paper does not attempt to describe a new method for socio-technical analysis and design; that is not its purpose. Nevertheless, we make two claims of our approach. First, we believe it has the potential for widespread application; indeed, in addition to the two topic domains described above, it has been used on issues as wide ranging as new product introduction, resilience, tele-health, security, open data, project management, risk analysis and accidents. And second, the approach has been used predictively, as illustrated above.

In the next section, we offer an outline agenda for research and development that we believe will take socio-technical thinking and practice forward.

5. An agenda for research and development

We take the view that most contemporary problems in society are, at least in part, systemic in their origins and will often require systemic analyzes and solutions. We acknowledge this is not a novel proposition but, interestingly, the point has not been widely debated or taken forward by socio-technical theorists or practitioners (c.f., Mumford, 2006). Whether the unit of analysis is within individual organizations (as has traditionally been the focus in socio-technical systems thinking; see Eason, 2008) or across a network of organizations (as in crowd events, such as the Hillsborough football stadium disaster), we argue in favor of systemic understanding. The application of such thinking beyond the traditional single organization may well require a reappraisal of what constitutes a socio-technical system (and is more in line with other systems thinkers, such as Checkland, 1981).

But the shift is more than moving beyond work within single organizations to analyzes of wider systems of activity; a further shift in emphasis is implied. Part of the on-going mindset amongst socio-technical thinkers arises as a reaction to the primacy of technology in practice. Our thinking and practice has been, in no small measure, a reaction to technological innovation and change (Clegg, 2000; van Eijnatten, 1997). However, as in the examples above, 'technology' plays roles of varying significance in systems. The implication is that the socio-technical community moves beyond its dominant focus on new technologies to a concern for complex systems (within which technologies, tools and infrastructures will play roles of some kind) (Walker, Stanton, Salmon, Jenkins, & Rafferty, 2010). This will almost certainly require a shift in our mindsets.

We propose that socio-technical systems thinking can be applied to major societal challenges concerning topics such as security, crime, resilience, sustainability, demographic changes, the provision of health and social care, the design and functioning of future cities and the like. All of these challenges require a degree of systemic understanding. Our claim is that socio-technical thinking and practice have the potential to offer added value through careful analysis and improved understanding.

To be clear, we are not arguing that this will be the only, or indeed the major, source of understanding and action, but systems thinking does, at the very least, have a potential contribution to make. Thus, we propose that people engaged in socio-technical thinking extend their conceptualization of what is meant by systems and widen the range of application domains. It is unlikely that such problems will be bounded within single organizations; accordingly we will have to become accustomed to working across numerous organizations and with a wide range of stakeholders and actors (e.g., Challenger et al, 2011).

We propose there is also a need to undertake more predictive work. Put another way, is it enough to just be wise after the event? We need to invest some of our effort in predictive work that helps identify potential problems and solutions in advance. In this view, socio-technical thinking is a design science (c.f., Simon, 1996) and we need to be more confident in applying our expertise to the design of new systems (e.g., Mumford, 1983) and in making predictions about anticipated consequences of design decisions. We have illustrated how systems thinking was applied in advance to identify risks for London 2012, and to inform the design of workplace initiatives on environmental sustainability. We take the view that this will be hugely challenging, but that this will force us to raise our game.

Work of this kind will necessarily involve other disciplines since it is highly unlikely that such problems will fall neatly into pre-packaged disciplinary silos. In other words, we need to work with researchers and practitioners from a broad range of backgrounds (c.f., Eason, 2008). Our experience is that other disciplines, and in particular engineering colleagues, are keen to work with people who have expertise on the 'social' aspects of socio-technical systems, since many readily acknowledge that engineering solutions to problems may be necessary but are rarely sufficient. The logical corollary of the above is that we need to work with a range of key stakeholders, including end-users, where users are broadly defined to include people engaged in the problems under examination.

All of these proposals will be massively challenging but it would, in our opinion, re-invigorate socio-technical thinking and practice. We take the view that social science, at least in part, develops 'bottom up', that we 'learn by doing' (Cassell & Johnson, 2006). The use of systemic ideas to understand, reflect and make predictions for practice is a learning opportunity. It also opens up a further challenge, that we use these new application domains to reflect on our theories and to improve them (c.f., Hodgkinson & Healey, 2008). That is not to say this is the only way in which theory develops, but to make the argument that applied social science, at least in part, evolves and develops in this cycle. This is entirely consistent with the traditional ways in which socio-technical theory and principles have been developed, that is 'bottom-up', from an emphasis on addressing real-life problems on the ground (e.g., Klein, 2005).

All of these proposals will also require the refinement of our existing toolsets and the development of new methods, so that we are better placed to analyze, understand, predict and evaluate complex socio-technical systems (e.g., Crowder, Robinson, Hughes, & Sim, 2012; Walker, et al, 2010). We will need innovations in our toolsets, for example, including innovations such as simulation and modeling, social network analyzes, the use of 'big data' and the like. We will also need to compare and understand what different toolsets offer and their suitability under different circumstances.

Finally, an ambitious agenda of the kind proposed here will also require that we re-invigorate our educational and training materials. How will we educate the next generations of students, managers, trade unionists, consultants, end-users and stakeholders so that they can contribute fully to this agenda? Implicit in all of this is the investment of greater effort and resources.

7. Concluding remarks

Our core argument is simple to articulate though admittedly difficult to deliver. In our view, people engaged in the forefront of socio-technical thinking and practice need to be braver in three interrelated respects. Thus, we need to:

- Extend our conceptualizations of what constitutes a system;
- Increase substantially the domains of application to include a much wider range of complex problems and global challenges; and
- Engage in more predictive work.

Clearly this will not be easy and not without risk, but the potential benefits are that we will be in a position to contribute to some of society's most challenging problems and, thereby, have a much greater social impact. Such an ambitious agenda for the future of socio-technical thinking will increase the opportunities for continuing theoretical advancement in ways that can only be good for our community.

7. References

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